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Title: IMAGE PROJECTION SYSTEM

## FIELD OF THE INVENTION

This invention relates generally to image projection systems, and is concerned more particularly with systems that include a spatial light modulator (SLM) for imparting image information to a projected light beam. Systems of this type typically are used for large screen televisions, which are often referred to as "electronic projectors".

## BACKGROUND OF THE INVENTION

In a typical electronic projector, the SLM may be a liquid crystal device (LCD) comprising a matrix of individually addressable liquid crystal pixels. Each pixel can be switched between a transmissive mode in which incident light from the light source passes through the pixel and is projected, and a non-transmissive mode. In the non-transmissive mode, the light may be reflected away from the projection lens. In any event, each pixel has an "on" state and an "off" state. By appropriately controlling the pixels in accordance with stored data, image information is imparted to the projected light beam.

U.S. Patent No. 5,584,991 (Levis et al.) discloses an example of an LCD projection system.

Another example of an SLM that includes an active matrix of pixels is known as a deformable mirror device (DMD). In this case, the matrix comprises an array of tiltable mirrors, each of which is a cantilever beam element carrying electrodes that allow the element to be electro-statically deflected between two positions. The extent of the deflection can be controlled by the applied electro-static potential to provide variable degrees of deflection, or the device can be operated in a binary manner so that each mirror switches between an "on" state and a "off" state. The mirror angularly deflects the incident light beam so that the beam is either reflected through the projector optics, or not.

DMDs are described in some detail in a paper by Larry J. Hornbeck entitled "Current Status and Future Applications for DMD-Based

Projection Displays". The paper is available on the Internet web site of Texas Instruments.

Known projection systems in which light from a light source is modulated by an SLM suffer the disadvantage that there is often a limit on the amount of light flux that can be directed into the SLM. This limit is caused by, for example, limitations associated with the heating effect of the radiant flux, or saturation due to high luminous flux.

Another problem with SLMs is that there is a tendency for some of the incident light to be scattered or reflected, which reduces the overall contrast of images projected onto the screen.

An object of the present invention is to address these disadvantages with the aim of improving the contrast of the projected images.

## SUMMARY OF THE INVENTION

The present invention provides a projection system that includes a light source for projecting a light beam, a screen, a projection lens for projecting the light beam onto the screen, and an SLM for imparting image information to the light beam upstream of the projection lens. Light leaving the SLM is polarized in a defined orientation by first polarizer means, and light passing through the projection lens is polarized in the same defined orientation by second polarizer means.

Generally speaking, the first polarizer means pre-polarizes or "characterizes" the light. Light that is subsequently scattered within the projector and depolarized will be partially blocked (up to a maximum of 50%) by the second polarizer means. Accordingly, the contrast ratio of the projected image will be increased by a factor of up to 2.

An advantage of the invention is that it is somewhat easier to characterize the unwanted "noise" (scattered light) by polarization than by trying to characterize the signal in some other way. Inefficiencies in the polarizing material are below significance since the amount of noise is relatively small compared to the signal. Inefficiencies such as inequities in performance depending on wavelength or angle of incidence can be tolerated

much more readily when applied to the noise component of the overall signal.

Additional significant improvements in the contrast ratio of the projected image can be made by coating or covering surfaces within the projector from which light tends to scatter, with a material that polarizes the light in an orientation that is orthogonal to the orientation of the light that is incident on the SLM.

## BRIEF DESCRIPTION OF DRAWINGS

In order that the invention may be more clearly understood, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention by way of example, and in which:

Fig. 1 is a schematic illustration of an electronic projector in accordance with a preferred embodiment of the invention; and,

Fig. 2 is a schematic perspective view of a pixel of a DMD that may be used in the projector of Fig. 1.

## DESCRIPTION OF PREFERRED EMBODIMENT

Fig. 1 illustrates schematically the principal components of a projection system in accordance with the invention. Reference numeral 20 denotes a light source that projects a beam of light 22 onto a projection screen 24 via a projection lens 26. The light source 20, projection lens 26 and screen 24 are essentially conventional. Also conventional is a beamsplitter arrangement comprising an assembly of prisms 30 that optically splits the light beam 22 into red, green and blue components (R, G, B). The respective components are directed by the beamsplitter to three corresponding DMDs 32.

The DMDs are essentially identical but deal with different portions of the spectrum. In other words, the light that enters the beamsplitter is split into red, green and blue components which are delivered to the respective R, G and B DMDs. The beamsplitter then in effect "re-assembles" the R, G and B components of the light beam and directs them together into the projection lens 26 for projection onto the screen 24.

Each of the DMDs 32 comprises an array of reflective digital

light switches (mirrors) that are integrated onto a silicon chip capable of addressing the switches individually. Each switch represents a single pixel in the array and can be individually switched on or off in accordance with digital information that is provided to the chip by an appropriate hardware and software controller. Each individual pixel in each DMD is controlled to impart appropriate image information to the light beam that is projected onto the screen 24.

Fig. 2 shows a single one of the mirrors of a DMD and part of the silicon chip used to control the mirrors. Since DMDs are known, detailed information with respect to the construction and operation of the DMD is not provided. Reference may be made to the Hornbeck article referred to previously for additional information. For present purposes, it is sufficient to note that Fig. 2 shows the mirror at 34 and that the mirror is mounted at the outer end of a cantilever beam element 36 carrying electrodes (not shown) that allow the element to be electrostatically deflected between two tilted positions, in which the mirror either reflects light into the projection lens 26 (Fig. 1) or away from the projection lens. In Fig. 2, the mirror is shown in full lines in one of its tilted positions and in ghost outline in the other of its tilted positions.

A portion of the silicon chip on which the mirror is mounted is denoted by reference numeral 38. The chip includes individual memory cells, one for controlling each mirror. By virtue of the construction of the DMD, the top surface of the chip 38 below each mirror (indicated generally at 38a) has surface portions that are at different elevations and have a variety of different irregular shapes, as indicated generally by reference 40 in Fig. 2. Pursuant to an aspect of the invention that is to be described later, the top surface of the chip is covered or screened by a sheet that is denoted 42.

In accordance with a primary aspect of the invention, the projection system includes first polarizer means for polarizing, in a defined orientation, light leaving each DMD and second polarizer means for polarizing, in the same defined orientation, light passing through the projection lens. The first polarizing means pre-polarizes or "characterizes"

the light in a defined orientation. Light that is subsequently scattered within the projector and de-polarized is then blocked by the second polarizer means and will not impair the contrast of the images that are projected onto the screen.

In the embodiment shown in Fig. 1, the first polarizer means is indicated by a polarizing filter P1 in the beam of light that enters the beamsplitter from the light source 20. For example, the polarizer may be positioned between lens elements 44 that configure the light beam appropriately before the light enters the beamsplitter. In this way, the light is pre-polarized or "characterized" by polarizer P1.

Polarizer P2 is also a polarizing filter and in this embodiment is positioned at the outer end of projection lens 26. Polarizer P2 has a defined orientation that is the same as the defined orientation of polarizer P1. Accordingly, polarizer P2 will block and prevent projection onto the screen of any light that has become de-polarized as the light beam passed through the optical system of the projector. It will of course be understood that polarizer P2 could be located, for example, within the projection lens 26 (e.g. between the lens element of the projection lens) or upstream of the projection lens as indicated in ghost outline at P2'.

Similarly, the location of polarizer P1 can change. Preferably, the light is pre-polarized before it reaches the SLM(s) of the projection system. However, it is important merely that the light be polarized as it leaves the SLM(s). For example, it is to be understood that the invention may be applied to a projection system that uses SLMs in the form of liquid crystal devices (LCDs). An LCD typically comprises front and rear polarizers and a liquid between the polarizers that "twists" the light that enters through the first polarizer so that it can exit through the second polarizer when the LCD is "on". Accordingly, the light is inherently polarized as it leaves the LCD. Accordingly, while there may nevertheless be advantages to using an upstream polarizer P1 in such an embodiment, it is to be understood that this is not essential and that reliance may be placed on the polarizing effect of the LCD itself.

In summary, the arrangement of first and second polarizers provided by the invention has been found to lead to significant improvements in the contrast ratio of the images that are projected onto the screen. It has also been found that additional significant improvements in contrast ratio can be achieved by coating surfaces within the projector from which light tends to scatter, with a material that polarizes the light at an orientation orthogonal to the orientation of the light that is leaving the SLM. For example, sheets of quarter-wave polarizing material or other appropriate coating materials can be used. In Fig. 1, the undulating lines denoted by reference numeral 46 indicate typical areas in which such coatings may be applied. One significant area is the top surface of the memory chip 38 of each DMD. Thus, reverting to Fig. 2, the sheet indicated at 42 may comprise such a material. Sheet 42 effectively screens from reflection by the surfaces 40 light that may "miss" or partially miss the mirror 34 and that would otherwise give rise to significant optical noise within the projector.

An additional benefit of the invention is that it reduces the heat load on SLMs in those situations where the light output by the projector is required to be polarized in a particular orientation. This is the case for example in a 3-D projection system where two sets of images are produced, one for each eye, and are characterized or coded by orthogonally polarized light. In a traditional system the light is usually polarized after the projector lens, resulting in an efficiency loss of roughly 50%. This loss of efficiency requires high input light levels to be used, which can lead to excessive heating of the SLMs. The invention avoids this excessive heating by polarizing the light before the optics of the projector, therefore reducing the radiant flux and associated heating on the SLM.

In conclusion, it should be noted that, while the preceding description relates to a particular preferred embodiment of the invention, the invention is not limited to this embodiment. A number of modifications have been indicated specifically and others would be apparent to a person skilled in the art. In addition, it should be noted that while the described embodiment relates to a projection system that includes three DMDs, projection systems

can be configured using different numbers of DMDs, for example, one or two. Different configurations are possible depending on the intended application of the projection system and the characteristics that are required of the system. Generally speaking, one and two DMD systems require time multiplexing of colour.